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MAXILLA BONE EVALUATION AND IMPLANT SURGICAL PLANNING IN A PERIODONTAL DISEASE PATIENT

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ABSTRACT

Knowing the value of biomodeling techniques - associating medical image segmentation with additive manufacturing, as a complimentary diagnose mean in the bone evaluation in complex and sensible anatomical areas (Queijo et al., 2010) it has been possible to support the diagnostic of a 50 years old female patient suffering from periodontitis who has lost an large amount of maxilla bone. At same time, by determining quantity and quality of maxilla bone in the affected area, the surgical planning have been made recurring to complete and fractioned biomodels in order to correctly define implants placement.

INTRODUCTION

With bone loss possibly caused by several reasons as a major constriction for dental implant placement, it is absolutely imperative that dental surgeons perform a correct evaluation of bone quantity and quality in actuation areas. Even that some different material and techniques have been developed in the attempt to promote bone regeneration, in most cases that isn't a common practice, being preferable an accurate tool that allows correct bone evaluation. Actually dental surgeons have at their disposal different complementary diagnose means that allow them to quantify maxilla's bone improving, this way, accuracy in surgical planning for a correct implant placement. This is the case of biomodeling techniques.

Biomodeling technique, that associates image segmentation to additive manufacturing has revealed itself as a valuable clinical activity valuable tool. Starting with bi-dimensional medical images from computerized tomography (TC) or magnetic resonance (MRI) is possible to obtain digital tridimensional models with the ability of being produced as physical models. These present major benefits when compared with conventional techniques once personalized tridimensional anatomical models can be visualized, manipulated and shown to the patient to better understand the nature of surgical intervention as well as the possibility of manufacturing dedicated surgical guides (Queijo et al., 2010).

BIOMODELING PROCESS

Biomodeling process refers to a divided technique that employs tools from digital image processing and additive manufacturing processes, often recurring to iterative operations that allow 3D digital models to be obtained and the manufactured.

In the conversion process of a computerized tomography in to a 3D model, it is needed a sequence of cross sections from the study object. Using 3D re-construction software it is possible to transform these bi-dimensional images in a three-dimensional model that can be

used to produce a solid model in rapid prototyping equipment. Images obtained from computerized tomography obey to the international standards from DICOM (Digital Imaging and Communications in Medicine) pattern. Those are obtained from axial cuts of the study area and the equipment should be settled to the less possible thickness, once the lower this value is, better will be the model quality (Foggiatto, 2006).

Additive manufacturing is the automated fabrication of physical objects. It is an additive-constructive process, layer by layer that allows complex form objects direct production from three-dimensional data and that is used to manufacture solid prototypes. The used geometry data can proceed from CAD systems or 3D Scanners, Computerized Tomography or Magnetic Resonance devices. In all additive manufacturing processes is used a 3D digital model that is translated into an STL (Stereolithography) format file where all the model surfaces are converted in to a triangle mesh.

In Biomedical Engineering field, using additive manufacturing techniques it is possible to produce several types of anatomical models and implant replica with educational purposes or to better understand a specific patient pathology. The models, depending of available techniques and the usage purpose, can be made of several materials like paper, wax, ceramic, plastic or metal. These models can be produced without finishing or color or have these finish operations done later to improve visualization. With educational purpose it is possible to manufacture implant replica with much lower cost than the implant value.

In surgical area, biomodels can be used and are a particular aid, not only to pre-surgical planning as well as post-surgical evaluation. In particular case of implant surgical planning, it can help to evaluate bone quality in the desired area to be treated and allow previewing the best places to implantation.

For biomodels fabrication, several manufacturing processes are available today, as Fused Deposition Modeling (FDM), Stereo-lithography (SLA), Selective Laser Sintering (SLS), Tridimensional Printing (TDP or 3DP) and Laminated Object Manufacturing (LOM) among other specific processes.

PATIENT'S CASE

In this study, patient is a 50 years old woman who suffered from chronicle periodontitis without knowing it until the symptoms have revealed it. When presented to the dental surgeon, 12th, 13th, and 14th teeth shifted so severely that almost had been lost when taking dental prints. They had to be removed in order to perform treatment and to allow posterior implant placement.

Simultaneously, bone quality in affected area needed to be confirmed to allow correct implant placement and analyze what kind of bone regenerations needed to be performed.

Periodontitis disease is the destruction of the supporting structures housing the tooth. If a sufficiently large amount of supporting bone and ligamentous attachment is lost, then the patient may present with a chief symptom of tooth migration or movement, loose teeth, and even tooth loss (Zwetchkenbaum and Taichman, 2008). Chronic periodontitis is usually asymptomatic until the disease is so severe that teeth shift, loosen, or are lost. Individuals with advanced periodontitis may also have recurrent periodontal abscesses and halitosis (Pihlstrom et al.).

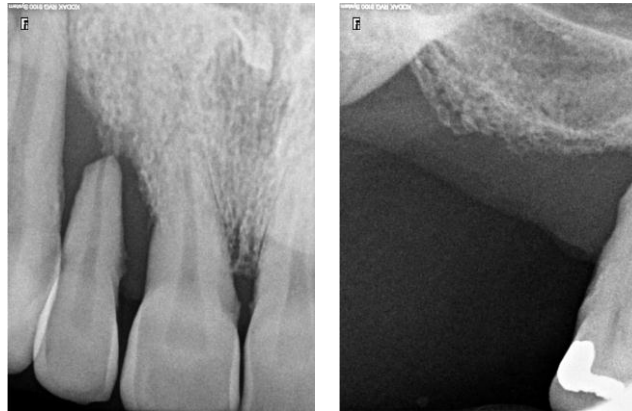


Fig. 1 Affected area radiographies

METHODOLOGY

After patient's authorization for TC images be used, these were transferred to the computer where would be done image processing and removed all personal information data.

The process to obtain the anatomic model is composed by the following steps:

- Pre-processing from bi-dimensional images and re-construction from the surface between the contours is done in specific image processing software. It is done by using image processing operation such as threshold, floodfill and paint that allow the creation and masks differentiation, based in image grey levels. These masks are defined through the color choice done by user giving contrast degree to the model for an easier visualization as well to enlighten the desired elements.

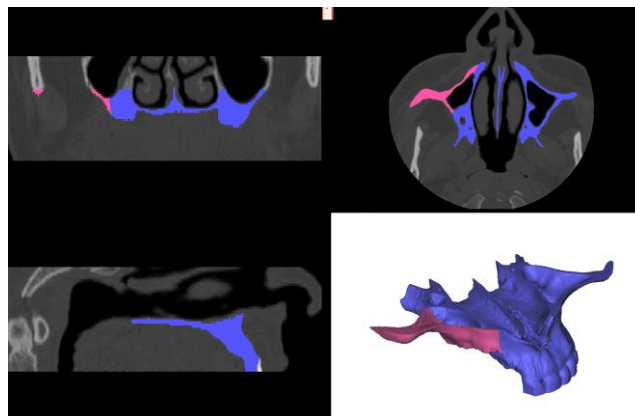


Fig. 2 Pre-processing and mask creation

First step of conversion consisted in 3D representation through the image processing application that allow closed volume visualization, after a segmentation operation based in the signal intensity – thresholding. This interactive application allow to detect and select contours in the maxilla area by doing a redefinition of grey levels that led to a separation of the bone from soft tissues. This operation applies gray levels recognition algorithms allowing a bigger grade of automatization.

Once obtained the contours with the desired quality, those are enhanced in a manual way using paint and floodfill and paint operations. These consist in adjusting the contours to the shape of the elements intended to represent and model.

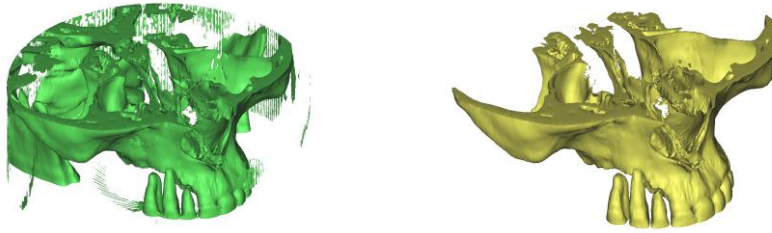


Fig. 3 Image pre-processing

- Rendering and 3D visualization allow following work development during the previous step, to detect and correct possible imperfections. 3D rendering is done by the application of a consecutive planar triangle mesh from the masks defined in previous steps. Combining these two last phases it is possible to do an iterative process with the objective of obtain the model as close to the reality as possible. In this case, not only a complete maxilla model has been produced, but also a global model divided in two sections aiming the diseased area and with the objective to allow a better view of the width of cortical bone along the maxilla.



Fig. 4 Rendering and 3D Visualization

- .stl data generation has the aim to convert all the active masks in a single file or the creation of several files with distinct masks. Data contained in these files consist in data translated from the 3D model mesh outputted from image processing software in to a printing format recognized by the rapid prototyping device. After processing, another type of file is generated (.sli or .slc) containing the model layer division in a way to allow the layer by layer printing.

- Model manufacturing in additive manufacturing device Zprinter 310 from ZCorp.

In the images from figure 6 it possible to visualize several phases from model manufacturing, going from the layer impression until the cleaning of the residual dust.



Fig. 5 Model manufacturing

• Finishing tasks includes removing and recycling the excess material and model material consolidation. Cleaning operations consist in the global remove, through the action of compressed air, the non-used dust to obtain an irregular but non dusty surface. After that, model surface consolidation is done by applying a glue layer to allow model proper manipulation.



Fig. 6 Cleaning and consolidating operations

RESULTS AND CONCLUSIONS

Biomodeling techniques prove themselves as a valuable complementary diagnose tool in bone condition evaluation and surgical planning when applied in dental disease situations. In this particular case, with a periodontitis disease, it has been fundamental to allow proper surgical planning and implant placement definition once maxilla bone in the concerned area was in a sensible situation.



Fig. 7 Model case analysis

After clinical examination (periodontal and radiographic) has been proposed rehabilitation with 3 implants (12th, 14th and 16th teeth and a 5 teeth bridge with nasal sinus elevation in 16th tooth). With the explanation of clinical protocol and osseointegration and cicatrization times, patient has chosen a simplest solution with 12th and 14th teeth implants.

Manufactured biomodels allowed a 3D visualization and, consecutively, a better understanding of maxilla condition in the disease area. In the models have been defined were the bone needed to be expanded as well as implant locations and orientation.



Fig. 8 Critical areas and implant placement definition

After teeth extraction and alveolar curettage the implants have been placed. In 12th tooth, after drilling, has been processed a bone expansion recurring to osteotome in order to correct vestibular bone loss. In 14th tooth, bone has been expanded to nasal sinus to avoid compromising his primary stability. Some defects have been corrected with autologous bone.

Implants have been placed in 12th and 14th teeth in a first phase and a metal-ceramic crown bridge evolving 12th till 15th teeth has been used in a second phase.

In case of having a post-surgical TC exam it would be possible to process it and obtain a new model that would show implant placement and compare it with the planned previously. However, this phase is often avoided due the examination costs and the need of protecting patient to excessive amount of radiation. Normally, post-surgical evaluation, in simplest cases, is done recurring to visual confirmation and to 2D radiographic exams.

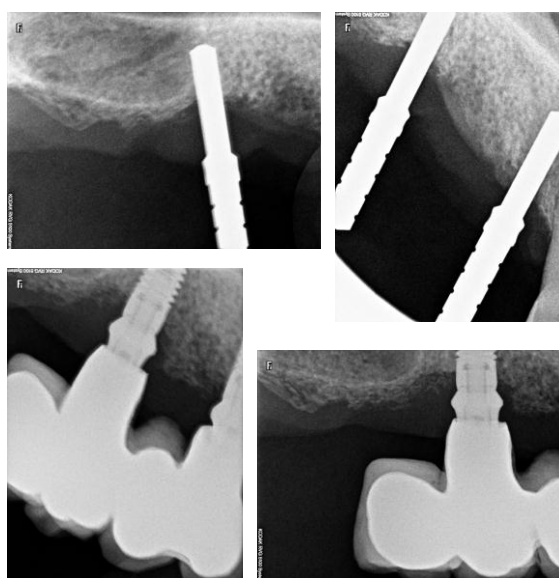


Fig.9 Post-surgical radiographic evaluation

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